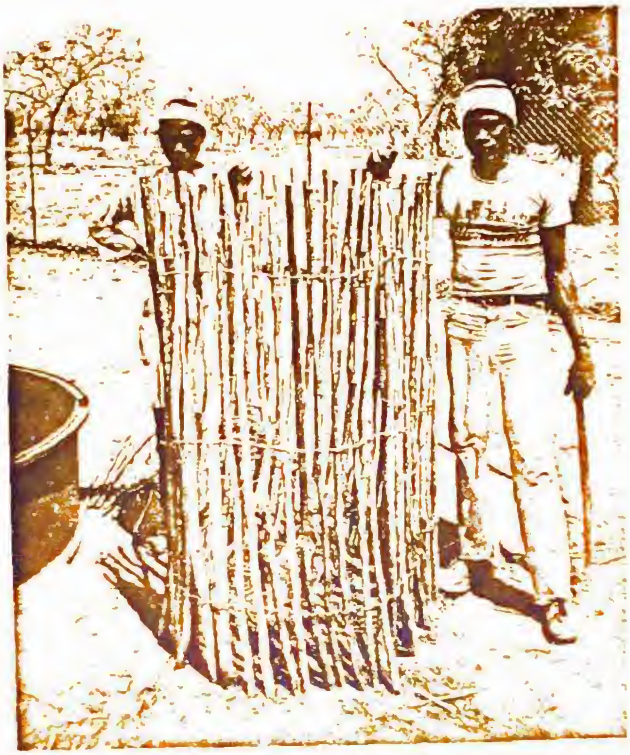
Design and Use of

AN APPROPRIATE TECHNOLOGY FENCE MAKING MACHINE

for Forestry Enterprises



USAID Project No. 686-0235

in cooperation with the Ministry of Environment and Tourism

Bobo-Dioulasso, Upper Volta

March 1984

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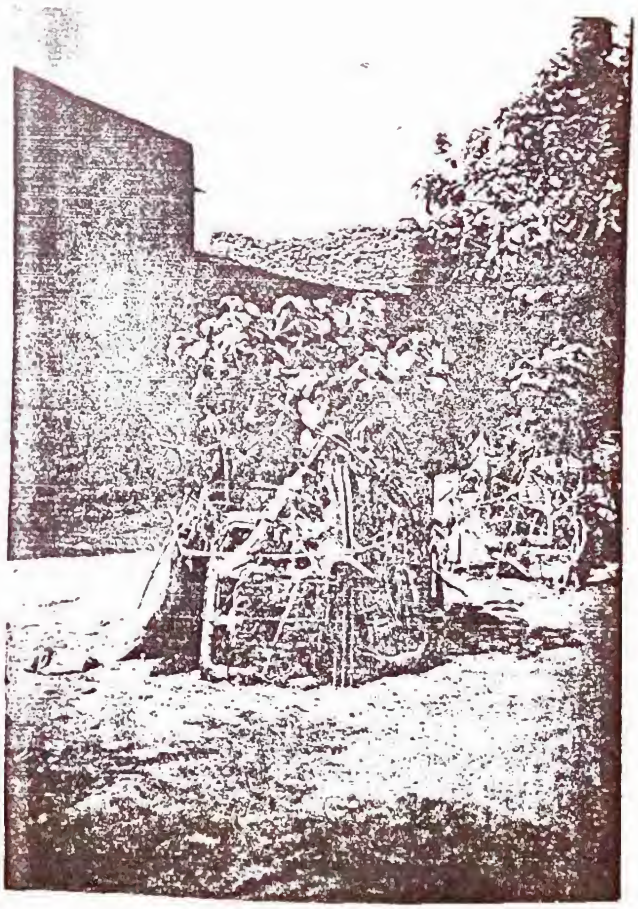
THE NEED FOR FENCING

Protecting young trees from foraging livestock is a major problem in Upper Volta and throughout much of the Sahel. The problem is especially acute in cities and villages due to the concentration of livestock.

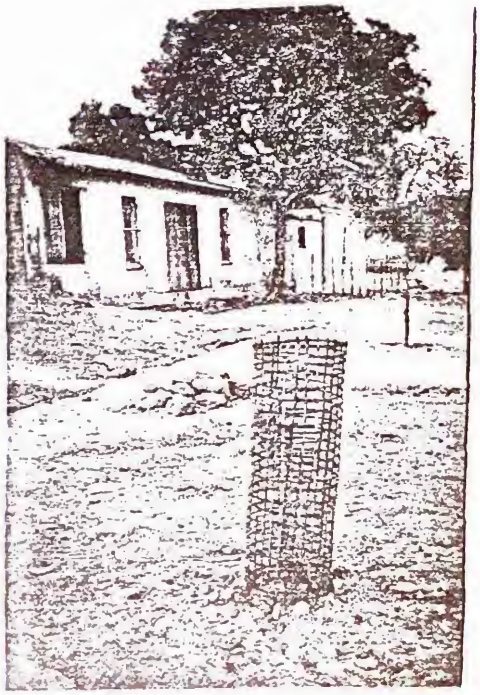
Many cities and villages are badly in need of more street-side trees to provide benefits such as shade, fruit, improved microclimate, dust and noise control, medicinal and dietary supplements, and even firewood from prunings and mortality. It only makes sense to maximize the growth of trees where their benefit to the people is maximized.

Individual efforts to establish street-side trees are often unsuccessful, not because of neglect or inadequate watering, but because hungry animals often manage to penetrate homemade tree protectors. Many residents who would like street-side trees may not even attempt plantings because of the low chance of success and the effort and expense required to construct and maintain tree protection.

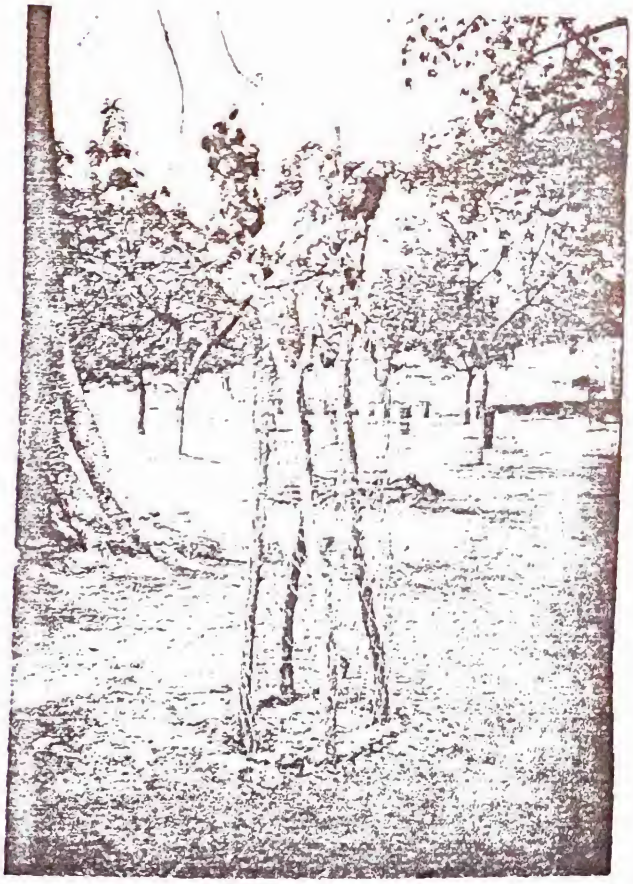
Following are a few examples of homemade tree protectors:



A tree protector made from junk metal, sticks, and wire. Careful construction and constant repairs are needed for this unwieldy and unattractive protection method to be effective.

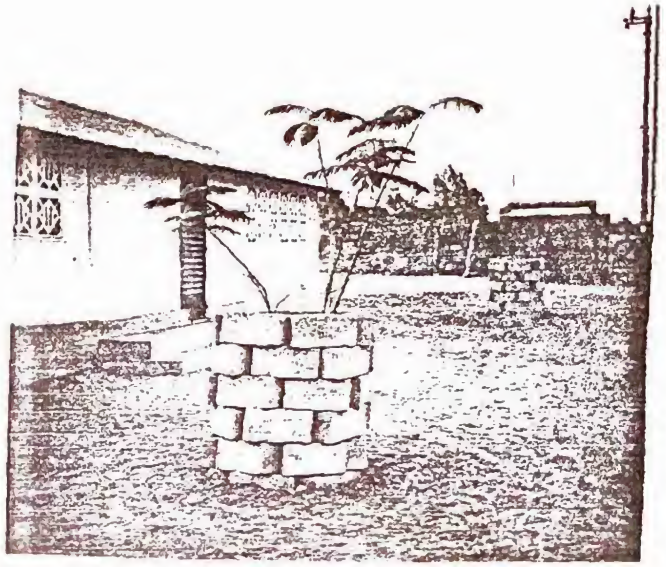


Steel banding salvaged from shipping crates is sometimes used to fabricate tree protectors. To maintain a reasonable degree of strength, the diameter of these protectors cannot be very large nor can they be too tall. No doubt the dark steel banding builds up heat considerably higher than air temperature creating an unfavorable environment for young trees.



This tree protector is made from a two x two meter piece of steel mesh normally used for reinforcing concrete. The mesh is supported by four wooden posts. There were several protectors of this design where this photo was taken, most of the protectors were badly dented and deformed. The cost of the steel mesh is probably in the range of 1500 - 2000 CFA*.

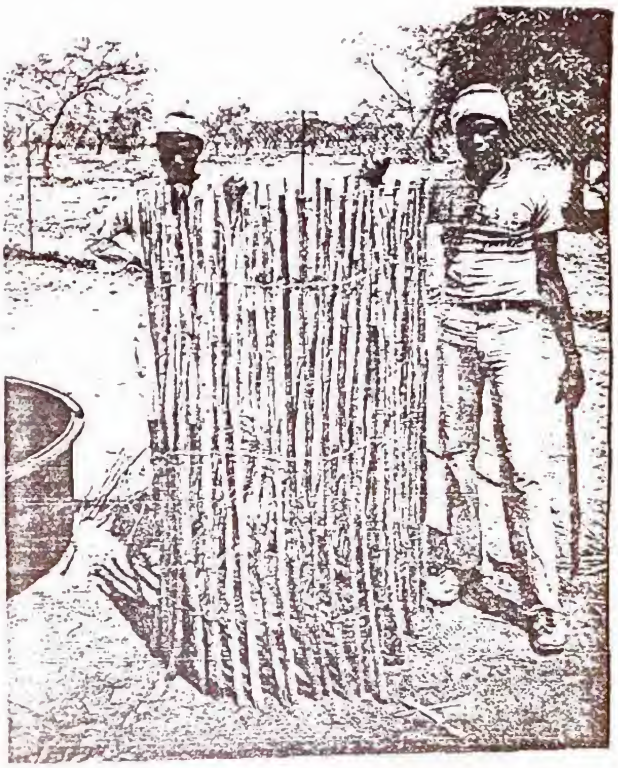
* the exchange rate at the time of this report was $1.00 U.S. = 400 CFA



Relatively expensive but effective tree protection made from cement blocks. Assuming a price of 100 CFA per block, each protector would cost 3600 CFA. The loose blocks could be a hazard to young children.

If street tree planting in cities and villages is to reach the level needed, there must be an ample supply of tree protectors which are relatively inexpensive, strong, long lasting, easy to install, and reasonably attractive. The protective enclosures should also provide a favorable environment for young trees and not cause heat build up or excessive shade. For adequate protection and growing space, enclosures should be about a meter in diameter and 1.5 meters tall.

One answer to the tree protection problem fits in nicely with the Department of Water, Forests, and Tourism's (Eaux et Forêts) forest management and harvesting operations. Straight branches and coppice thinnings 2-6 centimeters in diameter, which previously had little or no value, can be woven together with wire into sections of fencing ideal for individual tree protectors.



An individual tree protector made from eucalyptus coppice thinnings woven together with wire. The enclosure is made by forming a 3 meter long by 1.5 meter high section of coppice fencing into a circle around four support posts driven into the ground.

THE FENCE MAKING MACHINE

Making branch and coppice fencing without specialized tools is difficult and produces an inferior product. The moderately heavy wire (±2.00 mm. in diameter) which is necessary for making strong fencing, cannot be twisted tight enough by hand or with pliers. A low cost, efficient, locally built machine was needed to produce high quality fencing in commercial quantities.

In reviewing an FAO/Norwegian Forest Research Institute publication entitled Integrating Forest Operations with Small-Scale Industrial Activities - Including Energy Conversion written by Olav Gislerud and Kjell Wibstad and published in 1981, it was noted that a fence making machine was being used at a forest utilization project in Gambia. From a photograph in the publication it appeared that the hand powered machine would be well suited for use in Upper Volta.

Sketches of the Gambian fencing making machine were obtained from Dennis Panther, forestry officer for USAID Africa in Washington, D.C. From the sketches, the working principle of the machine was clear, but the remaining challenge was to adapt the design so that it could be built from low cost parts readily available in Bobo-Dioulasso, Upper Volta.

The "Bobo Fence Maker" was designed to manufacture three meter long sections of fencing in heights of 1.0, 1.5, and 2.0 meters. It was constructed from mobylette (motor bike) parts, angle iron, channel iron, flat steel, pipe, and miscellaneous small parts purchased from mobylette dealers and repairmen, retailers of construction materials, junk dealers, and market vendors in Bobo-Dioulasso.

Following is a detailed listing of the parts and materials purchased:

Qty.	Description	Unit Price in CFA	Total Price in CFA
4	6 meter long pieces* of 35 x 35 mm. angle iron - new - from Brossette, a construction material retail outlet (cornieres de 35)	5,363	21,452
2	6 meter long pieces* of 40 mm. channel iron - new - from Brossette (fer à U de 40)	8,484	16,968
1	6 meter long piece* of flat steel 45 mm. x 8 mm. - new - from Brossette (fer plat 45x8)	7,168	7,168
	Sub Total For New Steel		45,588
5	rear pinion sprockets for motor bikes - new - from Camico, a motor bike dealer (pignons arriere)	2,744	13,720
2	small pedal pinion sprockets for motor bikes - new - from Camico (pignons pedalier)	2,505	5,010
3	motor bike drive chains - 106 links each - new - from Camico (chaines motrice - 106)	1,800	5,400
	Sub Total for New Motor Bike Parts		24,130

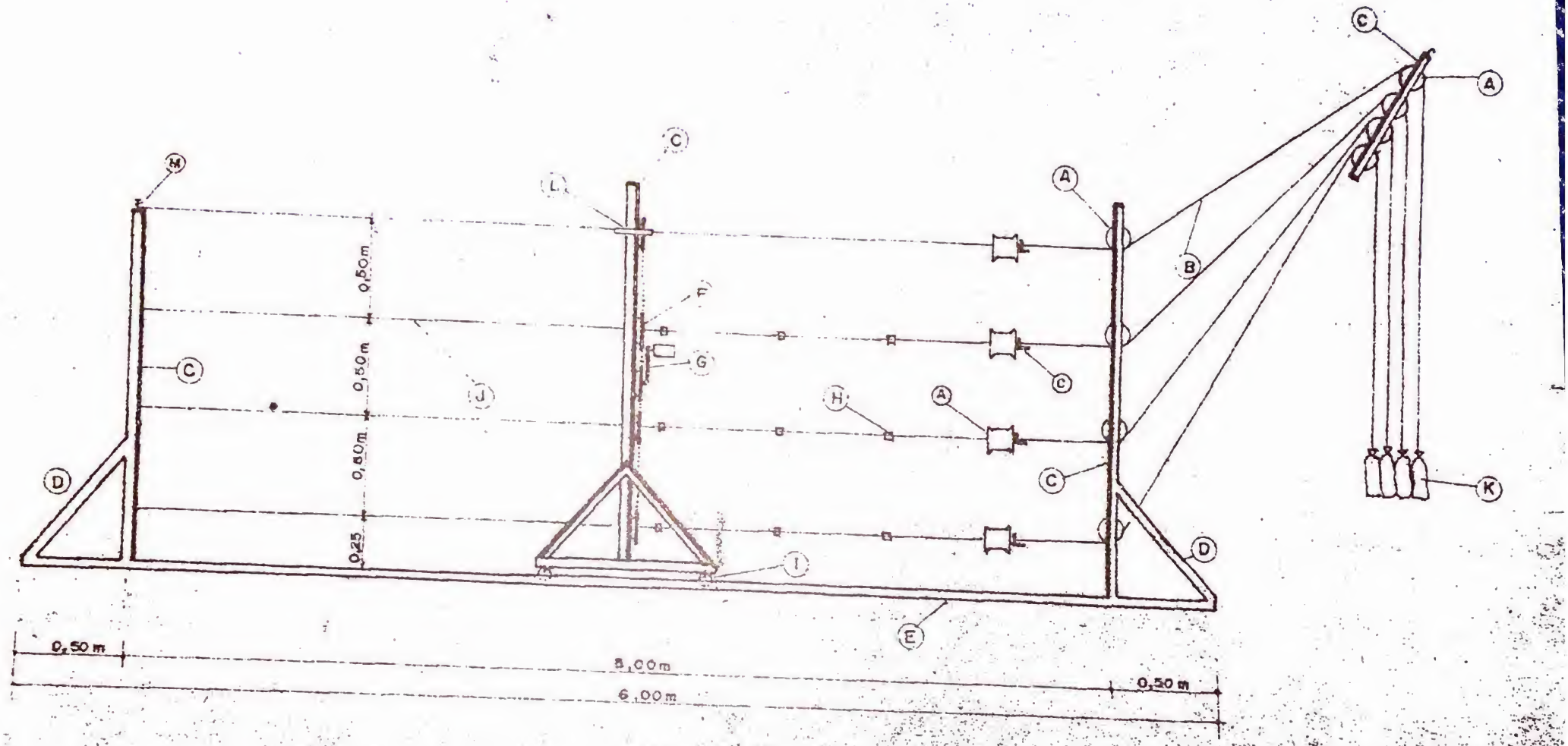
* these steel products were only sold in 6 meter lengths

Qty.	Description	Unit Price in CFA	Total Price in CFA
	Sub Total from Previous Page		69,718
5	rear wheel hubs for motor bikes - used & without axles or brakes - from motor bike repairmen (moyeu arriere de mobylette)	2,000	10,000
4	rear wheel hubs for motor bikes with good axles and bearings - used - from motor bike repairmen	2,500	10,000
8	front wheel hubs for motor bikes - used, but in good condition with good axles and bearings - from motor bike repairmen (moyeu devant de mobylette)	3,000	24,000
1	motor bike pedal - used - from motor bike repairman (pedal de velo)	600	600
	Sub Total for Used Motor Bike Parts		44,600
1	50 cm. long piece of steel pipe with an inside diameter of 9 cm. - used - from a junk yard	1,200	1,200
1	small piece of flat steel, approximately 5 mm. thick x 25 mm. wide x 20 cm. long for idler tensioning wheel arm - used - from a junk yard	150	150
1	small piece of pipe about 20 cm. long and with an outside diameter of 25 mm. to be used for axles for the small pedal pinion sprockets - used - from a junk yard	175	175
	Sub Total for Junk Yard Materials		1,525

Qty.	Description	Unit Price in CFA	Total Price in CFA
	Sub Total from Previous Page		115,843
32	meters of ±6 mm. diameter nylon rope - new - from market vendor	100	3,200
1	box of 100, 5 mm. x 25 mm. bolts with nuts - new - from market vendor		2,000
20	motor bike axle nuts - new - from market vendor	50	1,000
5	grease fittings - new - from Camico	35	175
1	spring for chain tensioning sprocket - new - from market vendor	25	25
4	woven plastic rice sacks - used - from rice retailer	75	300
2	wooden runners - new - from the sawmill at Eaux et Forêts wood yard	N/C	N/C
	Sub Total for Miscellaneous Parts		6,700
	TOTAL COST OF MATERIALS		122,543 (±$306 US)
±6	mandays of construction time*	1,500	9,000
	use of tools - hacksaw blades,* welding rods, drill bits, etc.		±30,000
	TOTAL COST OF THE "BOBO FENCE MAKER"		±161,543 (±$404 US)

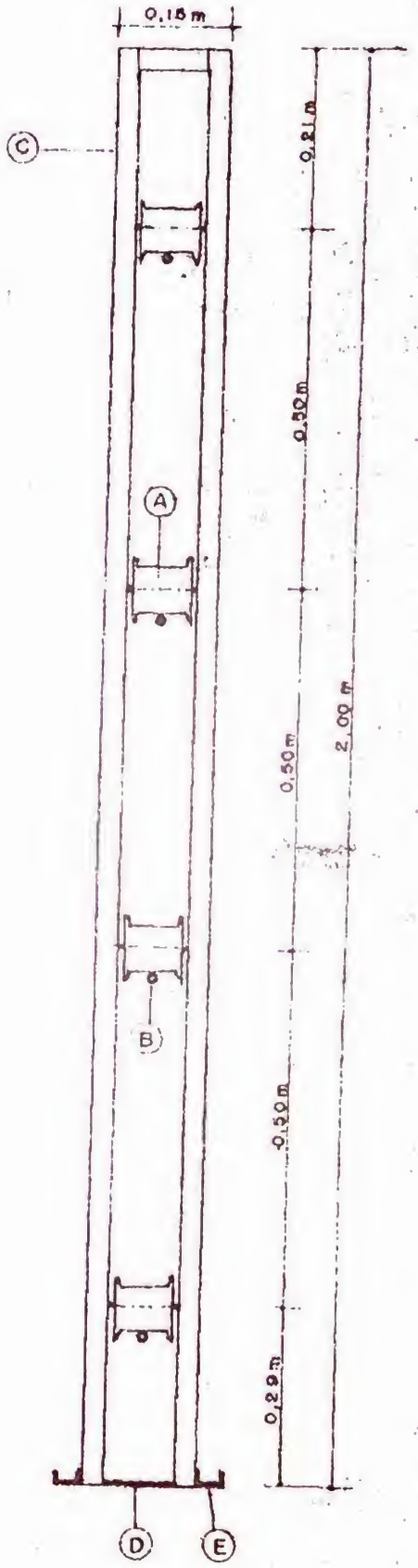
* for this machine not all these costs were directly incurred

Fence Making Machine

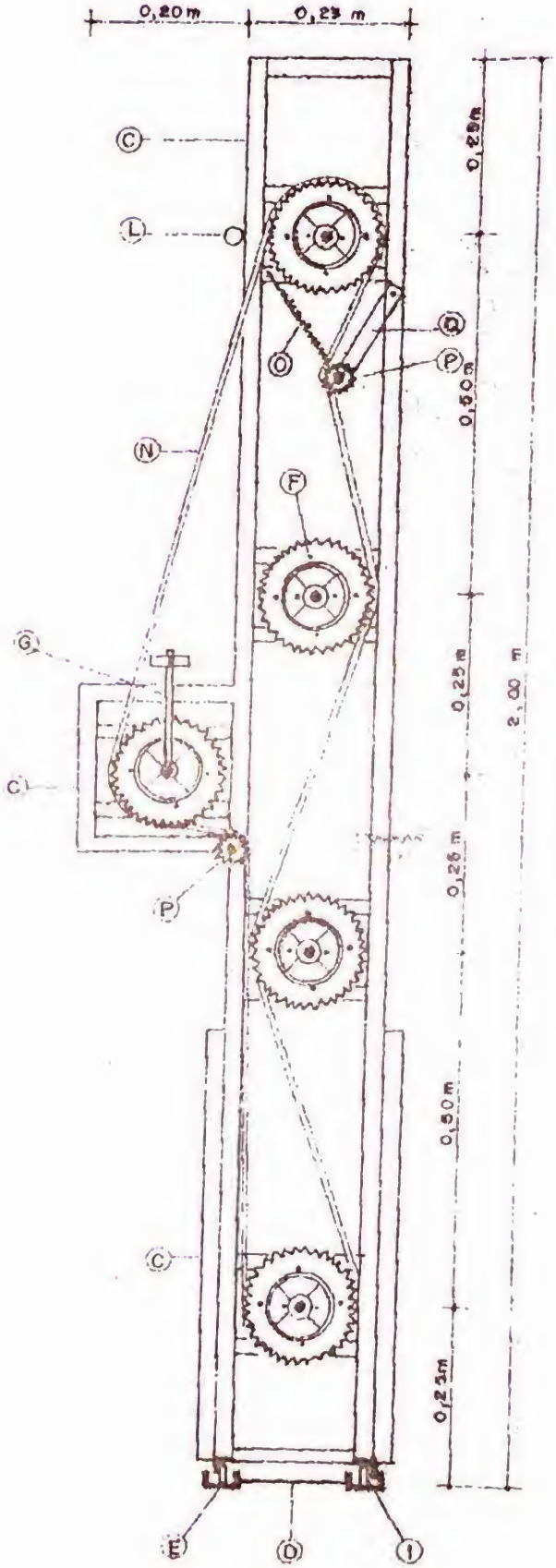


GUIDE Rollers

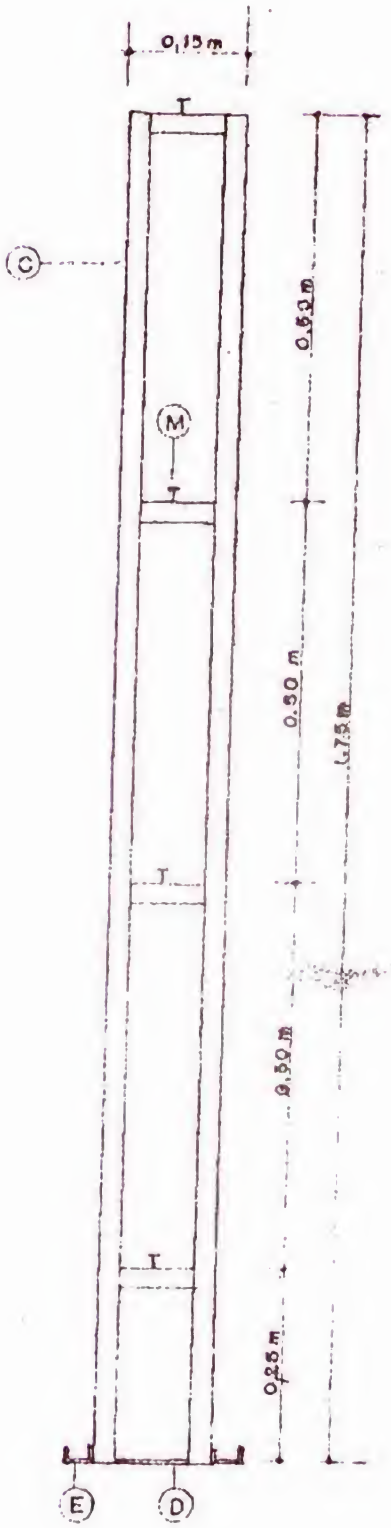
For Wire Tensioning Ropes



Wire Twisting Mechanism



Wire Anchoring Brackets



KEY TO FENCE MAKING MACHINE PLANS

Circled Letter	Description of Part
"A"	Wheel hubs from motor bikes - 5 rear wheel hubs without axles or bearings were used in the wire twisting mechanism - 4 rear wheel hubs with good axles and bearings were used for the wire swivels (front hubs may be used) - 8 front wheel hubs with good axles and bearings were used as guide rollers for the wire tensioning ropes.
"B"	±6 mm. diameter nylon ropes - these connect the wire swivels with the sand bag weights "K" to provide tension on the wires.
"C"	35 mm. x 35mm. angle iron - used for the framework of the wire twisting mechanism, the guide rollers, and the wire anchoring brackets. The main frame of the wire twisting mechanism and all the wire anchoring brackets are welded. The mounting brackets for the individual twisters are bolted in place so that adjustments can be made or hubs can be replaced if they wear. Both the fixed and hanging guide roller frames are bolted together so that hubs can be easily replaced if necessary. Heavier angle iron should be used for the framework of the fixed guide rollers and the wire anchoring brackets if it is available.
"D"	8 mm. thick x 45 mm. wide flat steel - used for bracing of the wire anchoring brackets and the fixed guide rollers - - 25 cm. long pieces were welded at regular intervals across the bottoms of the channel iron tracks, "E", to maintain uniform spacing between the tracks. Two, 3 mm diameter holes were drilled in each X-piece so that the track could be easily fastened down once the fence maker was installed in a permanent or semi-permanent location.
"E"	Parallel, 40 mm. wide x 6 m. long channel iron tracks. At each end and 50 cm. in from each end, small angle iron brackets were welded to the top side of the tracks for bolting on the wire anchoring brackets frame, the guide roller frame, and their respective braces. These components were bolted together rather than welded so that the fence maker could be easily taken apart and transported. Heavier, inverted, angle iron tracks should be used if grooved steel wheels can be purchased. (see "I")

KEY TO FENCE MAKING MACHINE PLANS

Circled Letter	Description of Part
"F"	Motor bike rear drive sprockets. Five sprockets are used for the wire twisting mechanism. Each wire twister consists of a sprocket bolted to a rear wheel hub which is free to rotate inside a bracket made of two, half sections of 9 cm diameter pipe each welded to an angle iron X-piece. Each hub has two, opposing, 3 mm. diameter holes, placed 3 cm. to each side of the hub center through which the wire is threaded.
"G"	Motor bike pedal. The rubber portion of the pedal was shaved down to comfortably serve as a handle. To make the twisting mechanism easier to turn when using relatively stiff wire, the length of the handle could be increased or the size of the driving sprocket decreased.
"H"	Wooden wire spacers. Three spacers are used between each pair of parallel wires, thus 9 spacers are needed when making 1.5 meter high fencing woven together with three wire pairs. Twelve spacers are used for 2.0 meter, 4 wire fence, and 6 spacers for 1.0 meter, 2 wire fence. The spacers are placed between the wires on the opposite side of the twisting mechanism from where the fence is being woven. The spacers nearest the twisting mechanism are 8-9 cm. long; the middle spacers are 15-16 cm. long; and the spacers nearest the wire swivels are 12-13 cm. long. The spacers have a small notch cut in each end so that they don't slip from between the wires. These spacers insure that the parallel wires on the non weaving side of the twisting mechanism do not twist around themselves, but instead transfer the twisting to the swivels.
"I"	Wooden slides. These slides were screwed to the bottom of the twister mechanism and aligned to slide easily within the channel iron tracks. Four small, grooved steel wheels running on parallel tracks of inverted angle iron would have allowed the twister mechanism to be moved with greater ease, but in the limited time available, such wheels were not found in Bobo-Dioulasso.
"J"	Two parallel wires.

KEY TO FENCE MAKING MACHINE PLANS

Circled Letter	Description of Part
"K"	Sacks filled with ±25 kg. of sand each. These sacks are the counter-weights which tension the parallel wire strands. This counter-weight arrangement maintains uniform tension while compensating for the slight shortening of the wires as they are twisted together.
"L"	A ±2 cm. diameter x ±10 cm. long pipe. A single taut wire runs from the wire anchoring bracket frame to the fixed guide roller frame straight through this pipe, serving only to prevent the twister mechanism from accidentally tipping over.
"M"	4 bolts, ±4 mm. diameter x ±2 cm. long welded to angle iron X-pieces. These serve as the fixation points for the first picket in when starting a new section of fencing.
"N"	Motor bike drive chain. Three, 106 link sections spliced together then slightly shortened to give the desired length.
"O"	Spring for chain tensioner.
"P"	Idler sprockets rotating on pipe axles. Two pedal pinion sprockets are used.
"Q"	Chain tensioner arm made from a piece of flat steel ±3 mm. thick x 3 cm. wide x 12 cm. long.

The IDA Forestry Project lent the use of their maintenance garage in Bobo-Dioulasso and the assistance of two mechanics for the construction of the "Bobo Fence Maker", since the USAID Forestry Project garage was not completed. Tools needed to construct the fence maker were as follows:

arc welder

hacksaw & ±10 high quality blades

power drill

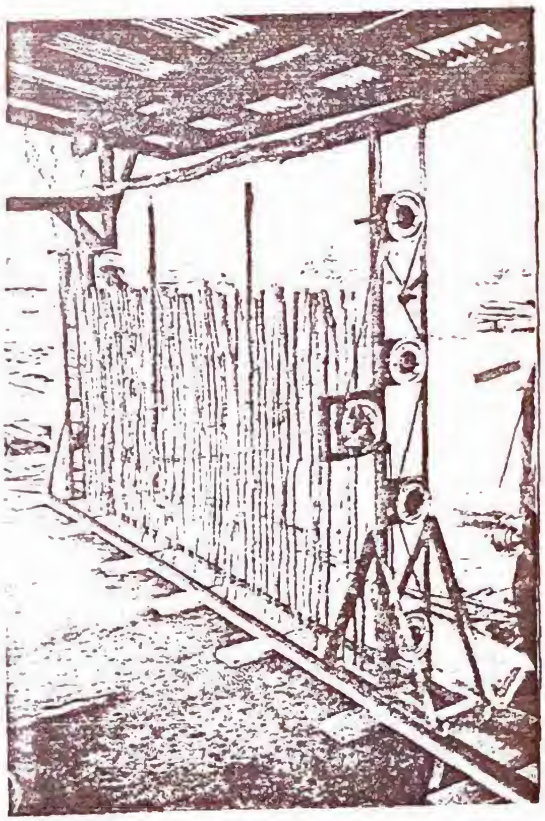
bench vise

power grinder, preferably hand-held

general tool kit of wrenches, pliers, screw drivers, etc.

MAKING THE FENCE

Before making any fencing, the "Bobo Fence Maker" should be set up in a flat location and securely anchored in place. Since this machine uses relatively light channel iron for tracks and light angle iron for the guide roller frame and the anchoring bracket frame, the machine will bend and slide, when the wires are tensioned. Thus it is necessary to anchor the tops of the roller and bracket frames with wire or rope. Since, in our case, the fence maker was installed in an open-sided building, each end of the machine was anchored with long wires to the building cross braces. The track was anchored to a board platform to increase rigidity and stability. As noted under "E" and "I" in the "Key to Fence Making Machine Plans" on pages 12 & 13, it would be preferable to use heavier angle iron for the roller and bracket frames as well as for the tracks.



The "Bobo Fence Maker" installed in an open-sided building. The track is anchored to a board platform for rigidity and stability. The fence section on the machine in this photo has its own support posts woven right in. While this method worked, it is easier to handle and install the fence if the support posts are not part of the fence section.

Several styles of fencing can be made using different materials, different lengths of materials, and different spacing between pickets.

Suggested materials for pickets are:

Eucalyptus coppice

Straight branches

Split Gmelina

Sawn lath

Bamboo splits

These picket materials can be cut to lengths of 1.0 meter, 1.5 meters, or 2.0 meters, depending on the height of the fencing desired. The number of wire twists between each picket determines the spacing.

Individual Tree Protectors are made from fencing sections 3 meters long by 1.5 meters high. Any type pickets may be used, but coppice, branch, or split Gmelina would be the most economical. Three to four wire twists are used between each picket to give a 6 - 8 cm. spacing.

Livestock & Utility Fencing of any length can be made by splicing together 3 meter sections. Fence height and picket spacing can be varied according to need, for example a poultry fence might need to be 2 meters high with 2 - 3 cm. between pickets while a 1 meter height and 8 - 10 cm. picket spacing might be sufficient for a sheep enclosure.

Bar, Restaurant, and Residential Fencing can be made using sawn lath as pickets. At the Eaux et Forêt wood yard (marché de bois), lath 1 cm. thick by 3 cm. wide was sawn from 1.0, 1.5, & 2.0 meter long logs of 10 cm. or more in diameter. The lath was woven into fencing using only one twist of the wires between each picket for a close spacing of ±1 cm. This produced very attractive and functional fencing.

All picket material should be well dried before being woven into fencing. If the fencing is woven while the pickets are still green, shrinkage during subsequent drying can cause unacceptable loosening of the wires. Sections of dry fencing may be treated with wood preserving chemicals, creosote, or used motor oil to prevent or retard decay and insect attack.

The "Bobo Fence Maker" can be operated by one person, but it is more efficient when two people work together. The normal sequence in making a section of fence is as follows:

- The sandbag counter-weights "K" are placed on a shelf or stand which is at least one meter high. This produces at least one meter of slack in the tensioning ropes "B". The stand is positioned just to one side of being directly under the hanging guide rollers.

- The first picket is attached to the wire anchoring brackets with ±20 cm. long reusable wire loops.

- A 7.5 - 8.0 meter length of wire is measured and cut for each set of parallel wires, "J", used in making the fence section. For example, a 1.5 meter high fence would require 3 sets of parallel wires. Ordinary, 2.00 mm. diameter, galvanized wire, purchased from Brossette (retailer of construction materials) was used. This wire was a bit too stiff, but did a satisfactory job. It would be advisable to experiment with different types of wire then purchase the preferred wire wholesale to save substantially on costs.

- Each length of wire is doubled back on itself, giving two parallel wires. The ends of the parallel wires are threaded on each side of the first picket then through their respective twisting mechanism. Pulling on the free ends of the wires from the opposite side of the twisting mechanism snugs the doubled end of the parallel wires up to the first picket.

- The free ends of the parallel wires are attached to their respective swivels. It is important to be sure the wires are attached through spoke or bolt holes in the hub swivel which are exactly on opposite sides of the swivel axle, otherwise the swivel will not rotate freely. Marking the proper holes with paint makes them easy to identify.

- Tension is put on the wires by lowering the sandbag counter-weights off the stand so that they hang free.

- Wire alignment is checked and adjusted, and the twister mechanism is slid up to the first picket.

- Wooden spacers, "H", are placed between the parallel wires on the side of the twister mechanism opposite the first picket.

- With the twisting hubs of the twisting mechanism only 1-2 cm. from the first picket, the wires are given one or more twists.

- The twisting mechanism is advanced a few centimeters and a picket is dropped in place between the wires.

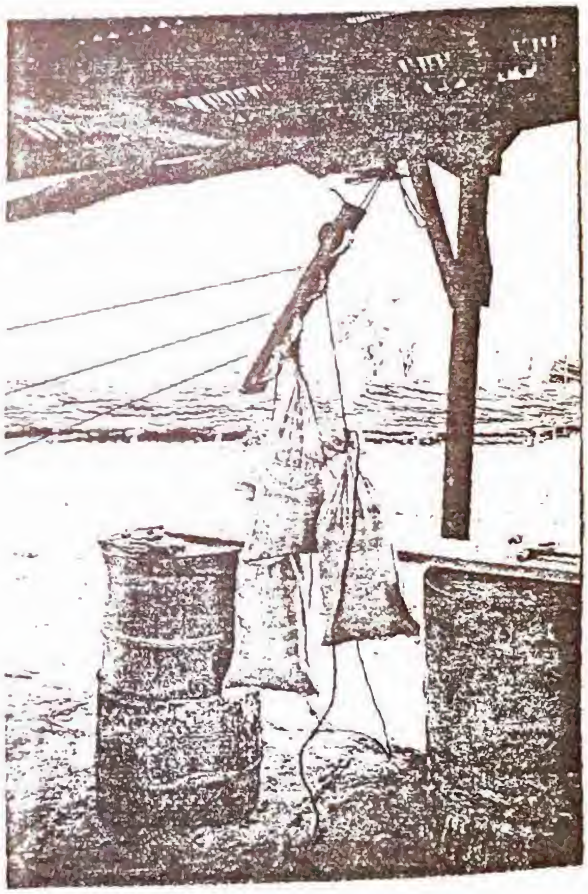
- Again with the twisting hubs only 1-2 cm. from the picket, the wires are given one or more twists.

- The twister is advanced, pickets inserted, and wire twisted in a repetitive fashion until a 3 meter long section of fence has been fabricated.

- When the fence section is finished, the sandbag weights are placed up on their stand. The ends of the wires are detached from the swivels, and pulled back through the twister hubs.

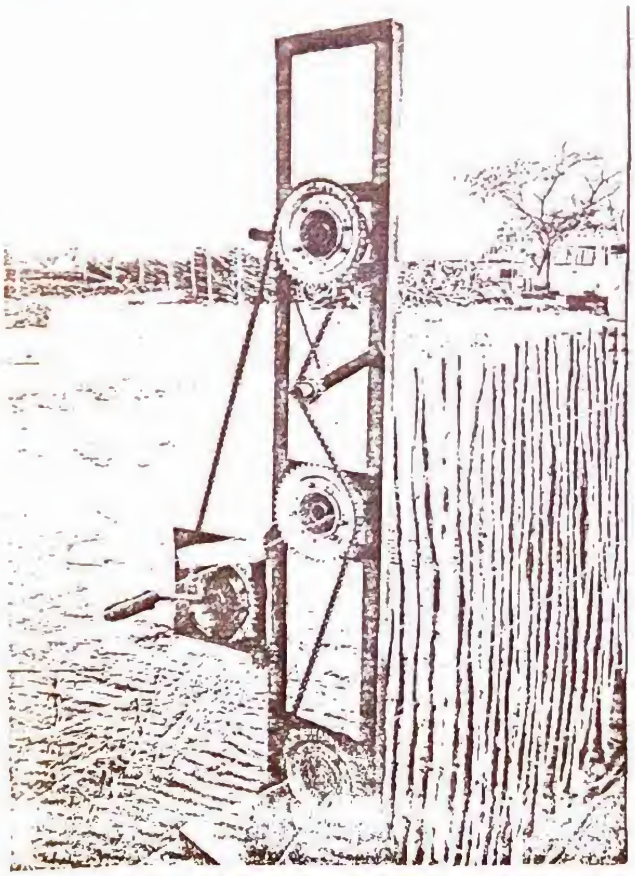
- Finally the reusable wire loops are unhooked from wire anchoring brackets, and the fence section is taken off the machine.

An average of about 20 minutes is required to make each 3 meter section of fence.



Sandbag counter-weights and the hanging guide rollers. To one side is a temporary stand made from old barrels and a board.

Close-up of a twisting hub. Note the ±3 mm. diameter holes on opposite sides of the hub center through which the parallel wires run. The mounting bracket for a twisting hub is made from two half sections of pipe welded to two angle iron X-pieces. The cross pieces are bolted to the twister mechanism frame. There is a grease fitting for each twister assembly. The picket furthest from the twister is the first picket in the fence section; it is anchored by reusable wire loops to the wire anchoring brackets.



The twister mechanism and a partially completed section of 1.5 meter high, coppice fencing. Note the wire spacers on the non-weaving side of the twister mechanism. The wire spacers are slid along toward the wire swivels as the twister advances.

THE ECONOMICS OF FENCE MAKING

Obviously the cost of fencing produced by the "Bobo Fence Maker" can be significantly affected by several factors which will undoubtedly be different from place to place and time to time. These factors are wire cost, picket material availability, transport distance, and labor rates. Machine cost is insignificant when divided by the number of fence sections which can be produced in the fence maker's projected life span.

Following is an example of fencing costs taken from our trials using eucalyptus coppice. This example is for a 1.5 meter high by 3 meter long section of fencing with three wires.

Wire Cost - One roll of 2.00 mm. diameter, ordinary galvanized wire purchased retail cost 3,195 CFA. Each roll was 200 meters long, thus yielding 25, 8 meter long pieces of wire for a cost of 128 CFA per piece. Three 8 meter long pieces, doubled back on themselves were used for each section of fence, thus the wire cost per fence section was 3 x 128 CFA or 384 CFA.

Material Cost - Coppice was assigned no stumpage value since it was obtained as a by-product of thinning. All the costs of properly thinning the coppice are assigned to final cost of the fencing. As demand for eucalyptus coppice increases with the popularity of the fencing and with the demand for chicken cages, a stumpage value should be assigned.

Harvesting Costs - (thinning) - One section of fencing requires ±40 pickets. These can be cut, limbed and loaded into a truck in an average time of 45 man-minutes or 0.75 hour. At a labor rate of 1000 CFA per day the harvesting cost is 94 CFA

Transportation Costs - Approximately 640 coppice pickets can be transported by a Jeep pickup, or sufficient quantity for about 16 fence sections. Round trip distance between the eucalyptus plantation and the fence making machine at the marché de bois was ±30 km. At a rate of 50 CFA per kilometer, the per trip vehicle cost was 1500 CFA or 1500 CFA/16 for a cost of 94 CFA per fence section. Allowing 1.5 hours per trip and a labor rate of 1200 CFA per day, the cost for the driver was 188 CFA per trip or 12 CFA per fence section. Thus the total transportation costs were 94 + 12 or 106 CFA.

Fence Making Labor - A two man crew should average 3 sections of fence per hour or 24 sections per day. Given a labor rate of 1000 CFA per day per man, this figures out to a labor cost of 83 CFA per section.

Machine Cost - Total machine cost, as shown on the bottom of page 7, was ±161,543 CFA. To be very conservative, the machine is assigned only a 5 year working life for these calculations and an additional 150,000 CFA is allocated for repairs over the same 5 year period. This gives a total 5 year machine cost of ±311,543 CFA or a yearly cost of ±62,000 CFA. Assuming the machine is used 200 days per year, producing 24 fence sections per day, the annual production will be 4,800 fence sections. Machine cost per section is then 62,000 CFA/4,800 or 13 CFA per section.

Miscellaneous Handling - An additional ±15 CFA per section should be allowed for incidental labor involved in stockpiling fencing, etc.

Summary of Costs per Fence Section

Wire	384 CFA *
Coppice Pickets	N/C
Harvesting	94
Transportation	106 **
Weaving Labor	83
Machine Cost	13
Misc. Handling	15
TOTAL COST PER SECTION	±695 CFA

* it should be possible to reduce wire costs substantially by purchasing wholesale

** transportation costs might be reduced slightly by using one of the project dump trucks

Two views of the "Bobo Fence Maker" set up for operation in the open before it was installed in an open-sided building.